Measurement and Comparison of Indoor and Outdoor Exposure Rates and Radiation Risks in Tantua-Amassoma, Bayelsa State, Nigeria

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ABSTRACT

Residential areas for university students are special places where they spend a lot of time and may be contaminated by radionuclides and radon. The necessity of radiation monitoring, mapping, and mitigation techniques to reduce potential health hazards is highlighted by the fact that prolonged exposure to background ionizing radiation can also result in neurological illnesses, reproductive issues, and carcinogenic and mutagenic consequences. The goal of this research is to analyze radiological risks both indoors and outdoors in a neighborhood that is primarily populated by university students. measuring the exposure rate in the area with the RADALERT. Findings indicate that both indoor and outdoor background ionizing radiation values are below global average of 0.013 mRh^{-1}. Mean values of absorbed dose, annual effective dose equivalent and excess lifetime cancer risk for indoor and outdoor are 103 $nGyh^{-1}$ and 89.2 $nGyh^{-1}$, 0.48 $mSvy^{-1}$ and 0.109 $mSvy^{-1}$ and 1.31×10^{-3} and 0.36×10^{-3} respectively. Also, indoor and outdoor effective doses to some body organs is ranged between (0.175 – 0.312) $mSvy^{-1}$ and (0.040 – 0.072) $mSvy^{-1}$ respectively with the testis having the greatest dose in both instances. In every measured and computed parameter, indoor values are greater. Therefore, it is advised that builders use caution when bringing supplies into the region to avoid raising the radiation level.

Key word: exposure, indoor, outdoor, excess lifetime cancer risk and body organs

INTRODUCTION

The increasing awareness of radiological hazards has become a significant concern globally, particularly in residential areas with high population density (UNSCEAR, 2012). University students' residential areas are unique environments where students spend a substantial amount of time, exposed to potential radon and radionuclide contamination (Olusegun et al., 2015; Liu et al 2020). In Nigeria, studies have shown that indoor radiation levels can be elevated due to the use of local building materials (Adewoyin et al., 2022). Exposure to radon, terrestrial gamma radiation, and cosmic radiation may pose specific hazards, such as lung cancer risk, contamination of water sources, soil pollution, and airborne radiation. Additionally, radioactive decay of building materials and natural radioactivity in soil and rocks may elevate indoor radiation risk. Prolonged exposure to background ionizing radiation may also lead to neurological disorders, reproductive problems, and carcinogenic and mutagenic effects, emphasizing the need for radiation monitoring, mapping, and mitigation strategies to minimize potential health risks (Echeweozo and Ugbede 2020). The area of Amassoma, Nigeria, may be susceptible to various radiation-related hazards due to background ionizing radiation, including increased cancer risk (e.g., lung, breast, thyroid), genetic disorders and birth defects, radiation sickness, and radiation-induced illnesses (e.g., radiation cataracts). Understanding the radiological hazards in university students' residential areas therefore is crucial for developing effective mitigation strategies and promoting radiation safety awareness (ICRP, 2007). This study's findings will contribute to informing radiation safety guidelines, enhancing student awareness and education, and improving residential area design and construction. By exploring the radiological hazards in this unique environment, the aim here is to offer a full insight of potential health risks associated with radiation exposure among university students. In Nigeria, researchers have investigated radiation levels in various environments, including residential areas (Okeyode et al., 2019; Oladele, et al., 2018). Previous studies have focused primarily on either indoor or outdoor radiological hazards, neglecting comparative assessments. However, there is a knowledge gap regarding the comparative analysis of indoor and outdoor radiation exposure among university students. This study seeks to address this gap by evaluating radiation levels in both indoor and outdoor environments, providing valuable insights into the radiological hazards faced by university students. This study aims to compare indoor and outdoor radiological hazards in a university students dominated residential area.

Study area

Amassoma is a coastal town in Bayelsa State, Nigeria (lat. 4.7°N, long. 6.1°E). Geologically, it's situated in the Niger Delta sedimentary basin, characterized by alluvial and coastal plain sands. The vegetation is predominantly mangrove swamp forest (Okiongbo and Mebine 2015). With a population of approximately 250,000 (Tariwari, et al., 2018), Amassoma is primarily inhabited by the Ijaw ethnic group. The indigenes are mainly fishermen, farmers, and artisans, with a growing student population due to the presence of the Niger Delta University (NDU) (Nwankwo and Aigbedion 2022).

MATERIALS AND METHODS

A portable digital radiation detector, the RADALERT 100X which measures background radiation by means of an inbuilt Geiger-Muller (G-M) counter. was used. The tube in the RADALERT produces a signal every moment radiation goes in to the tube then makes ionization to occur. It was factory-calibrated using a ^{137}Cs source enabling precise measurement of exposure in milli-Roentgen-per-hour (mRhr^{-1}) having ±15% accuracy. The regular range of operation is 0.0 - 110 mRh^{-1}. As soon as the radiation level reaches its maximum threshold, the Radalert 100X emits a distinctive three-second beep, followed by a three-second pause, repeating this cycle. Simultaneously, the display indicates 'Range: Full'. This audible and visual alert persists until the radiation level drops or the device is powered off. Data collection took place in twenty randomly selected apartment and average values were recorded. Selection was done to ensure that the whole community was well represented. Background ionizing radiation detection was equally done in twenty outdoor points, with a good spread to cover the study area. Measured radiation levels were used to determine other radiation risks.

CALCULATIONS

1 Absorbed dose is the energy deposited into human body or an object due to exposure to ionizing radiation (CNSC, 2012). The average exposure in mRh^{-1} obtained from the study area were transformed into absorbed dose rate in nGyh^{-1} employing equation 1

$$\text{I mRh}^{-1} = 8700 \text{ nGyh}^{-1} \qquad 1$$

2 Annual effective dose equivalent AEDE, is a key metric for assessing the potential long-term health implications of radiation exposure. AEDE has been estimated by employing equations 2 and 3 (UNSCEAR, 2008).

$$\text{AEDE (outdoor)} = \text{D x 8760 h x 0.7 SvGh-1 x 0.2 x } 10^{-3} \qquad 2$$

$$\text{AEDE (indoor)} = \text{D x 8760 h x 0.7 SvGh-1 x 0.75 x } 10^{-3} \qquad 3$$

Where D is absorbed dose rate in $nGyy^{-1}$, 8760 h is total hours a year, CF is dose conversion factor from absorbed dose in air to effective dose in Sv/Gy. CF = 0.7 Sv/Gy. OF is occupancy factor, period anticipated for people in the study area to stay outdoor, OF = 0.2 as proposed by UNSCEAR, 2008

3 The lifetime cancer risk refers to the likelihood of an individual developing cancer over their lifetime as a result of prolonged exposure to low-level radiation. This risk is calculated multiplying the estimated annual effective dose of radiation by the average human lifespan and a risk factor, as outlined by (Taskin et al., 2009).

$$ELCR = AEDE \times DL \times RF \qquad 4$$

Where AEDE is annual effective dose equivalent. DL, is average lifespan or life expectancy (55.2yrs) in Nigeria (WHO, 2018) and RF is risk factor for low dose background radiation, ICRP 60 used 0.05 Sv^{-1} for public (Taskin et al., 2009).

4 Effective dose rates to different body organs

The estimation of organ-specific radiation doses quantifies the amount of radiation absorbed by various tissues and organs. The effective dose rate to a specific organ can be determined using equation 5.

$$D_{organ}\,(mSvy^{-1}) = AEDE \times O \times F \qquad 5$$

Where O, occupancy factor, is 0.8

F (conversion factor for organ dose from ingestion = 0.64(lungs), 0.58(ovaries), 0.69(bone marrow), 0.82(testes), 0.62(kidneys), 0.46(liver), 0.68(whole body).

RESULTS

Tables 1 and 2 show indoor and outdoor exposure rate as well as other determined radiation-based parameters. Figures 1 and 2 display comparisons of background ionizing radiation with world average and ELCR values indoor and outdoor with world average. While effective doses to the body organs are shown in table 3 and 4.

Table 1: measured indoor radiological parameters

S/N	BIR (mRh^{-1})	ABD ($nGyh^{-1}$)	AEDE ($mSvy^{-1}$)	ELCR X 10^{-3}
1	0.010	87.1	0.40	1.10
2	0.015	130.5	0.60	1.65
3	0.009	78.3	0.36	0.99
4	0.011	95.7	0.44	1.21
5	0.017	147.9	0.68	1.87
6	0.011	95.7	0.44	1.21
7	0.012	104.4	0.48	1.32
8	0.008	69.6	0.32	0.88
9	0.014	121.8	0.56	1.54
10	0.010	87.1	0.40	1.10
11	0.014	121.8	0.56	1.54
12	0.013	113.1	0.52	1.43

13	0.013	113.1	0.52	1.43
14	0.012	104.4	0.48	1.32
15	0.010	87.1	0.40	1.10
16	0.007	60.9	0.28	0.77
17	0.014	121.8	0.56	1.54
18	0.014	121.8	0.56	1.54
19	0.013	113.1	0.52	1.43
20	0.011	95.7	0.44	1.21
MIN	**0.007**	**60.9**	**0.28**	**0.77**
MAX	**0.017**	**147.9**	**0.68**	**1.87**
AVERAGE	**0.012**	**103.53**	**0.48**	**1.31**
STDV	**0.002**	**21.66**	**0.10**	**0.27**

Table 2: measured and calculated outdoor radiological health risks at Tantua.

S/N	**BIR (mRh^{-1})**	**ABD (nGyy^{-1})**	**AEDE** (mSvy^{-1})	**ELCR x 10^{-3}**
1	0.007	60.9	0.075	0.243
2	0.016	139.2	0.171	0.555
3	0.013	113.1	0.139	0.451
4	0.009	78.3	0.096	0.312
5	0.012	104.4	0.128	0.416
6	0.012	104.4	0.128	0.416
7	0.009	78.3	0.096	0.312
8	0.015	130.5	0.160	0.520
9	0.001	8.7	0.011	0.035
10	0.011	95.7	0.117	0.381
11	0.01	87.0	0.107	0.347
12	0.011	95.7	0.117	0.381
13	0.008	69.6	0.085	0.277
14	0.01	87.0	0.107	0.346

15	0.012	104.4	0.128	0.416
16	0.014	121.8	0.149	0.485
17	0.008	69.6	0.085	0.277
18	0.007	60.9	0.075	0.243
19	0.012	104.4	0.128	0.416
20	0.008	69.6	0.085	0.277
AVERAGE	**0.010**	**89.2**	**0.109**	**0.36**
MIN	**0.001**	**8.7**	**0.011**	**0.04**
MAX	**0.016**	**139.2**	**0.171**	**0.56**
STDEV	**0.003**	**29.32**	**0.036**	**0.12**

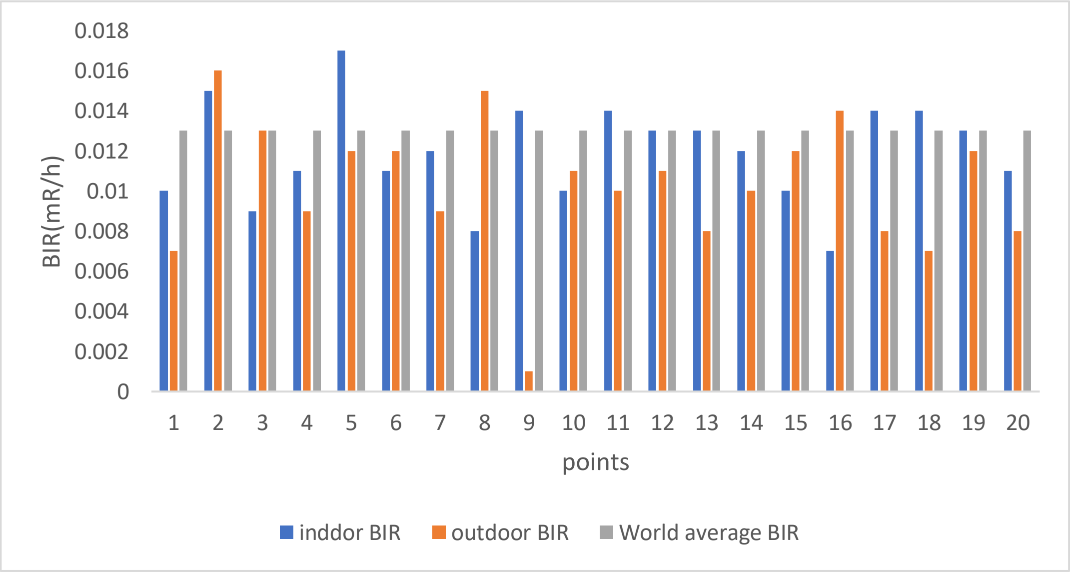

Figure 1: comparison of indoor and outdoor background ionizing radiation with world average

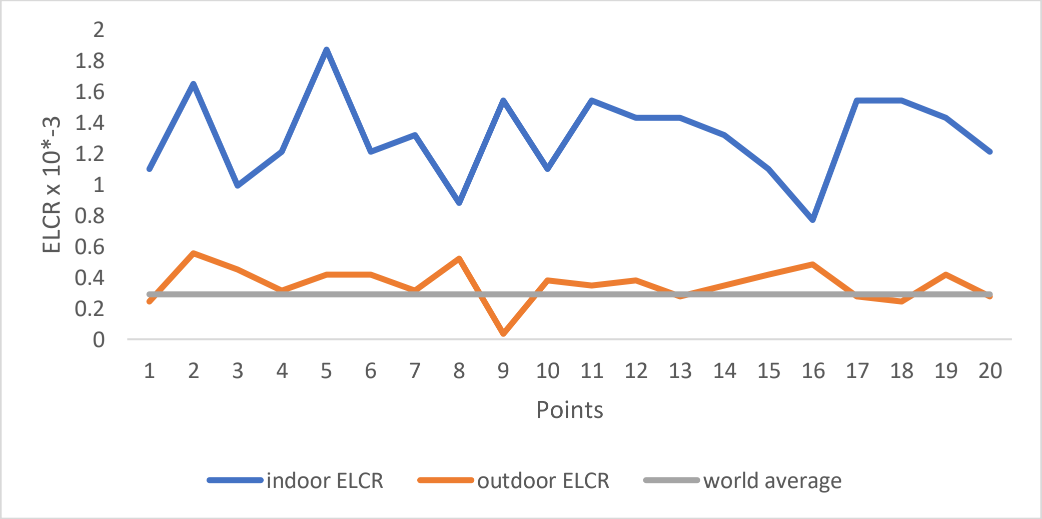

Figure 2: comparison of indoor and outdoor ELCR with world average

Table 3: effective dose to body organs due to indoor BIR

S/N	Body organ	Conversion factor	Organ effective dose	**World average
1	Lung	0.64	0.244	0.64
2	Liver	0.46	0.175	0.42
3	Kidney	0.62	0.236	0.62
4	Testis	0.82	0.312	0. 82
5	Ovary	0.58	0.221	0.54
6	Bone marrow	0.69	0.263	0.69
7	Whole body	0.69	0.259	0.68
Average			**0.244**	

Table 4: effective dose to body organs due to outdoor BIR

S/N	Body organ	Conversion factor	Organ effective dose	**World average
1	Lung	0.64	0.055	0.64
2	Liver	0.46	0.040	0.42
3	Kidney	0.62	0.054	0.62
4	Testis	0.82	0.072	0. 82
5	Ovary	0.58	0.051	0.54
6	Bone marrow	0.69	0.060	0.69
7	Whole body	0.69	0.059	0.68
Average			**0.056**	

**UNSCEAR, 2000; ICRP, 2007

DISCUSSION

The range of calculated absorbed dose rate values for indoor and outdoor is between (60.9 – 147.9) nGyh^{-1} and (8.7 – 139.2) nGyh^{-1} respectively with observed mean value of 103 nGyh^{-1} and 89.2 nGyh^{-1} for indoor and outdoor respectively. Mean dose rates calculated are above recommended safe limit of 84.0 nGyh^{-1}. They are however less than 147.46 nGyh^{-1} reported by Musa et al., 2024 and 132.16 nGyh^{-1} reported by Ugbede and Benson (2018). The range of annual effective dose indoor and outdoor is between (0.28 – 0.68) mSvy^{-1} and (0.11 – 0.171) mSvy^{-1} respectively with mean of 0.48 mSvy^{-1} and 0.109 mSvy^{-1} for indoor and outdoor respectively. The mean values recorded in this work were lower than world allowable value of 1.0 mSvy^{-1} (Musa et al., 2024). Excess lifetime risk calculated using annual effective dose equivalent for residential area is between (0.77 – 1.87) x 10^{-3} and (0.04 – 0.56) x 10^{-3} respectively, with mean of 1.31 x 10^{-3} and 0.36 x 10^{-3} for indoor and outdoor respectively. Though these values are all above 0. 29 x 10^{-3}, world average, they are below the suggested limit of 2.4 x 10^{-3} (Odoh, et al., 2019; ICRP, 2007). They are however lower than 3.21 x 10^{-3}, 4.21 x 10^{-3} and 1.83 x

10^{-3} reported by Qureshi et al., 2014; Ononugbo et al 2015 and Abba et al., 2023 respectively. Figure 1 is pictorial illustration showing comparison between indoor and outdoor BIR values from the student's residential area, against world average. It shows only 30% of indoor values are above the world average value. While 15% of the outdoor values are seen to be above the world average value. Figure 2 displays the contrast between indoor and outdoor ELCR with world average value. The figure shows all computed indoor results are above the world average while the outdoor values hover around the world average. From tables 3 and 4, the indoor and outdoor effective doses to some body organs is between (0.175 – 0.312) $mSvy^{-1}$ and (0.040 – 0.072) $mSvy^{-1}$ respectively. In both instances, the testis is seen to have greatest dose whereas the liver got lowest dose. All estimated values to organs analyzed are less than the worldwide acceptable limit on doses to body organs 1.0 mSv yearly (Ugbede and Benson, 2018).

CONCLUSION

This research focused on the determination of indoor and outdoor radiation level in students dominated area of Tantua, Amassoma Bayelsa state. The results obtained show that the average background ionizing radiation value indoor and outdoor are less than 0.013 mRh^{-1}, global average. Absorbed dose rate in air outdoor, is about world average while absorbed dose rate, indoor is above, 84.0 $nGyh^{-1}$, world average. Annual effective dose equivalent within the area in both scenario is lower than 1 $mSvy^{-1}$, world tolerable limit. However, excess lifetime cancer risk in both instance is above 0.29×10^{-3}, world average, with indoor rates more significant. This could be due to radioactivity in materials used for building houses. Also seen is that indoor exposure contributes more to dose received by body organs. From the results gotten during the course of this study, it is necessary that monitoring of background ionizing radiation should be regular in the study area to avoid increase in the future. Builders should be mindful of the type of materials they bring in to the area so as not to escalate the radiation level. There should be more awareness of ionizing radiation and its effect among dwellers the students' area.

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